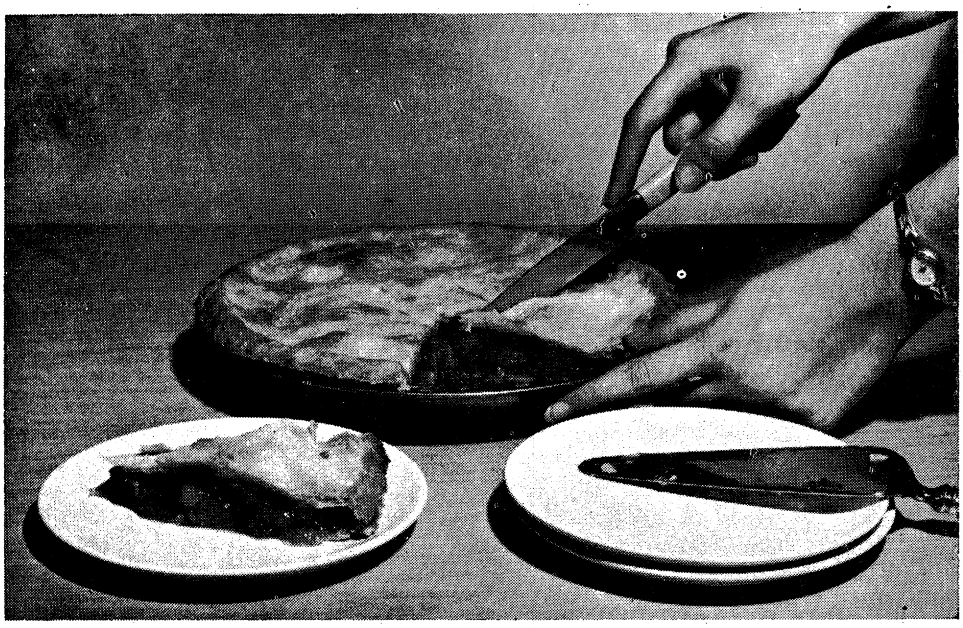

JUICE-TYPE apple pie was prepared from explosion-puffed slices. Boiled 5 min in sugar-containing water, explosion-puffed slices yield a flavorful compote.

Explosive Puffing Applied To Apples and Blueberries

Dehydration process yields rapidly rehydratable fruit that has pleasing flavor and appearance. Operating costs are comparable to conventional hot-air drying

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INCREASING DEMAND for convenience foods has led to the development of many new products. Available now are dehydrated soup mixes, dried potato products for hash browns and scalloped, and pie and muffin mixes.

Blueberry muffin mixes usually contain the fruit packed wet in cans. Although this type of pack is not necessarily inconvenient for the consumer, it represents shipping weight in excess of an equivalent dehydrated product.

Commercial bakeries may use dehydrofrozen, canned or dried apples. The first require frozen storage, the canned product is bulky to store, and dried apples require at least 5-hr soaking before use.

A dehydration process has been needed to fulfill the following objectives: (1) operable at a cost comparable to conventional hot-air drying; (2) capable of producing relatively large pieces of fruits and vegetables, and (3) obtaining products that reconstitute rapidly.

The "explosion puffing" process not to be confused with puff-drying, has been successfully applied to potatoes, carrots, beets, rutabagas, sweet potatoes, apples and blueberries.

The process described here for apples and blueberries is applicable to discrete pieces of fruits and vegetables. It yields products which can be quickly reconstituted to their original form. And, it consists of (1) partially dehydrating the fruit or vegetable pieces, (2) imparting a porous structure by explosion puffing, and (3) drying the porous pieces to a low moisture content.

Process for Apples

Block diagram, Fig. 1, shows process applicable to commercial operations. In the pilot plant work reported here, the varieties used were Stayman Winesap, Rome Beauty, Smokehouse and Northern Spy Apples. All yielded products of good quality.

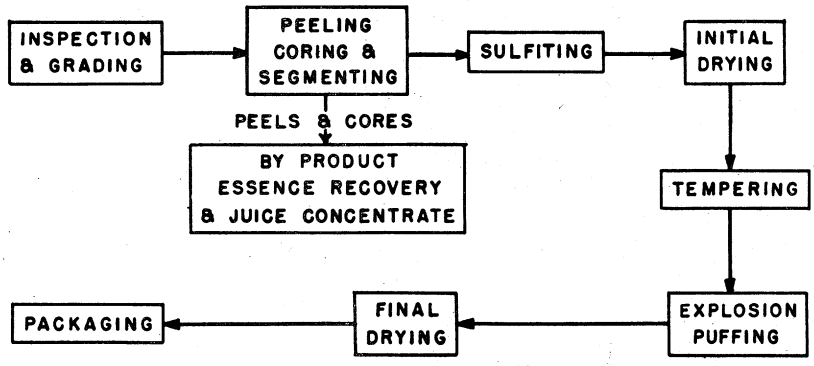

FIG. 1—Flowsheet indicates the essential steps in the process for explosion-puffed apple segments.

Preparation of Slices

Mature, sound apples, 2½ to 3 in. in diameter, were mechanically peeled, cored and sliced (12's) in a two-cup F. B. Pease Co. machine. In a commercial operation, the peels and cores could be used to make by-products such as essence and concentrate.

The segments were dipped in a sulfite and citric acid solution to control color during processing and storage. The length of dip and concentration can be varied to obtain the desired end concentration of sulfite. A concentration of between 200 and 500 ppm is required for dried apple pie slices for military use. A level of 300-500 ppm is recommended in the explosion-puffed product.

Initial Drying

Partial dehydration is required to reduce the moisture content to a suitable level for explosive puffing. Otherwise, disintegration of the piece would occur. For apples, the range of moisture content is between 20% and 30%. Below this range little puffing is achieved and the product is scorched. Above, the pieces tend to collapse after puffing.

Commercially, initial drying would probably be done in a continuous belt-type, hot-air dryer. Drying in the pilot plant was done in a cabinet-tray dryer (National Drying Machinery Co.) under conditions typical of commercial practice.

Slices were placed in a tray to a depth of 3¾ in. giving a loading of 10.4 lb per sq ft. Air was passed upward through the bed at 180-F dry bulb temperature, 100-F wet bulb at about 300 ft min, until 50% of the moisture to be removed was evaporated. Then air direction was reversed to downflow until slices were fully pre-dried. The time for initial drying to 25% moisture was 3½ hr and the final bed depth was 1¼ in.

Upon leaving the dryer, the slices are not of uniform moisture content. Uniformity is essential to obtain optimum results on explosion puffing; hence, a period of equilibration is desirable. Due to pilot plant processing schedule, it was necessary to hold the segments for 18-24 hr prior to explosion puffing. This was done at 38F, and the segments at the end of this period were uniform in moisture content.

Equilibration at room temperature should achieve a similar uniformity of moisture distribution in less time. Tempering facilities that are reasonably air tight should be provided to store the partially dehydrated slices during this period.

For the manufacturer who does not desire to equip a plant for the initial processing steps, commercially prepared apple pieces of about 25% moisture content are presently available. They are in the form of segments (pie slices), chips or dice. Drying facilities must be provided, however, to dehydrate the pieces after explosion puffing.

Explosion Puffing

The "gun" used in explosion puffing is essentially a rotating cylindrical pressure chamber that is fitted with a quick-release lid, and is heated externally. The pilot plant model used has been described. The rotational speed of the gun is fixed to give an optimum tumbling action of the charge. This speed (33 rpm) is about 40% of the critical speed, i.e., the speed at which centrifugal force and gravitational force are equal and no tumbling takes place.

The charge, usually 20 lb of material (10 lbs/cu ft of gun volume), is placed in the gun, the lid clamped, rotation started and heat applied. Heating causes vaporization of some of the moisture in the charge, thereby increasing pressure within the gun.

At about 25 psi, heating is stopped and the gun is lowered to about 40 deg below the horizontal. Rotation is continued for about 10 sec to move the charge toward the muzzle. The gun is then raised to the firing position (22 deg below the horizontal), and is fired, ejecting the contents.

The nearly instantaneous drop to atmospheric pressure vaporizes a small portion of super heated water within each slice, thereby imparting the desired porous structure to the piece. Explosion puffing usually reduces the moisture content by 5% on an absolute basis due to flashing of water.

In operating the gun, it is necessary to assure adequate warmup of the heating surface at the outset of a series of firings. The empty gun is closed, the gun surface heated to the desired operating temperature, and then fired releasing the air pressure built up in the gun. The normal charge is then loaded and repetitive firings continued.

It is essential to maintain a relatively constant and controlled surface temperature during heating of the charge. If the heat input to the gun exceeds that needed to heat the pieces uniformly, the piece surface will be scorched. A thermocouple is installed on the pilot plant gun to indicate gun-surface temperature, and the heat flux is controlled by manually adjusting gas flow to the burners.

In a commercial operation, automatic controls would be used. The maximum external surface temperature for apple pieces was found to be 425F. This usually requires about 2 min of heating because of the 30-F drop in gun-surface temperature between discharging and re-application of heat. The heat input is reduced to maintain this gun-surface tem-

perature until the desired pressure of 25 psi is attained. The total cycle between charging and discharging is about 11 min.

Final Drying

The puffed slices require further drying from about 20% moisture to a moisture content of 2% to insure good storage stability. Commercially, this would be done in a continuous belt, hot-air dryer. In the pilot plant it was done in a tray dryer—the same as initial drying—using throughflow air circulation at 150-F dry bulb temperature, 100-F wet bulb at about 350-ft/min velocity. Bed depth at the outset was 3 in. at a tray loading of 3.5 lb/sq ft; the final bed depth was 2¼ in.

Drying rates for puffed and unpuffed slices were essentially the same for both going down to 21% moisture. The rapid drop in moisture content to 16% of the puffed sample was due to the loss in moisture during puffing. The greatly increased drying rate of the puffed pieces is due to imparted porosity. Final drying to 2% moisture was accomplished in 5 hr for the puffed sample as contrasted with 12½ hr for unpuffed.

Process for Blueberries

Blueberries, as contrasted to apples, require little preparation prior to explosion puffing. Cultivated whole berries, obtained fresh from Michigan and New Jersey, were used in pilot plant runs. These were size-separated into two fractions of overs and unders from a 5/16-in. slotted screen and partially dehydrated (separately) to insure uniform drying.

Initial drying was done in a cabinet tray dryer with each tray containing 2 in. of berries at a tray loading of 7.8 lb/sq ft. Hot air at 200-F dry bulb temperature, 100-F wet bulb, was passed at a velocity of 300 ft/min in an upflow direction through the bed until 50% of the moisture to be removed had been evaporated. Then air direction was reversed until the berries were dried to the desired explosion-puffing moisture content. Initial drying time was about 2 hr, with a final bed depth of ¾ in.

A moisture content of 22% gave the best puff. However, good puffs were obtained within a range of 19% to 30%. The two fractions, dried under the same conditions except for time, were combined in a 20-lb charge. Both overs and unders puffed well at 25 psi.

Final drying was done in the dryer previously described with a bed depth of 2 in. and a tray loading of 3.0 lb/sq ft. Hot air at 150-F dry bulb and 100-F wet bulb was passed in a downflow direction at 300 ft/min. Drying to 6% moisture required about 2½ hr. The final bed depth was 1½ in. Sulfiting was not found to be necessary at any point during the processing.

Product Evaluation

APPLES. One expected end-use for apple slices would be in pies. Explosion-puffed pieces make excellent pies having a pleasing flavor and appearance. About 3½ oz of the dried product are adequate for a 9-in., juice-type pie.

Conventionally dried apple slices require a minimum 5-hr soaking before use. Slices which have been explosion-puffed are ready for use in pies after only 5-min boiling. Illustration on preceding page shows a juice-type pie prepared from puffed apples. When boiled 5 min in sugar-containing water, explosion-puffed slices yield a flavorful compote.

Similarly, commercially dehydrated apple pieces such as nominal ⅜-in. dice or "chops" may be explosion-puffed and dried to be eaten "as is." They may be used as an ingredient in dry cereals or made into a flavorful compote.

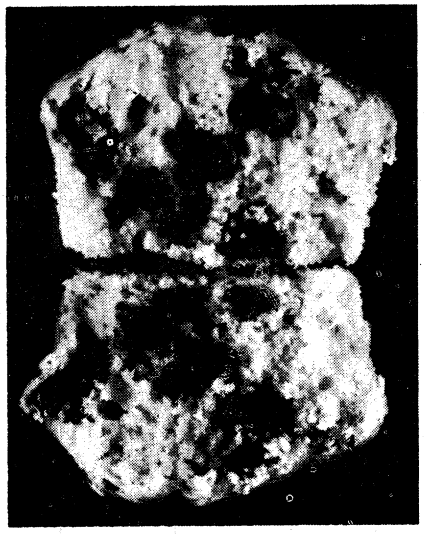

Fig. 2—Berries have soft, juicy character in muffins prepared from explosion-puffed fruit. Conventionally dried berries do not have this attribute.

Storage tests have not yet been made on explosion-puffed apple pieces. However, there is no reason to believe that keeping properties will differ from unpuffed pieces if their sulfite content is between 300 and 500 ppm.

BLUEBERRIES. Rapidly rehydratable blueberries, possessing a pleasing flavor, are well suited for use in baked products, e.g., prepared muffin mixes. After a 2 to 3-min boil the water is decanted, and the berries are stirred into the ingredients of a commercial muffin mix in place of the conventional wet pack.

Fig. 2 shows muffins prepared from explosion-puffed berries. It illustrates the soft, juicy character of the berries, an attribute not obtainable with the conventionally dried product.

Explosion-puffed dried blueberries may also be added to dry cereals in the manner that raisins are sometimes used. Unlike raisins, the berries have a crisp character compatible with the cereal. Explosion-puffed blueberries need only to be simmered for 1 min with a little water to be ready for use in a pie filling.

Processing Costs

It is presumed that a plant employing explosion puffing will process several commodities in order to extend the operating season over a profitable length of time. For example, a plant in New York State could process carrots, potatoes and apples over a 300-day operating season. Other commodities, such as beets and blueberries, could be made to order. Estimates show that the cost to make explosion-puffed products in such a plant would be only slightly higher than for the conventional hot-air dried products, and considerably less than that for freeze-drying.

ACKNOWLEDGMENT. The authors express their appreciation to Mrs. Florence B. Talley, Food Technologist, for evaluating explosion-puffed dried apples and blueberries.

NOTE: Reference to certain products or companies does not imply an endorsement by the Department over others not mentioned.